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(54) **Phantom for NMR apparatus.**

(57) A phantom for NMR apparatus comprises a structure of holes which are to be filled with a contrast medium so that when the phantom is imaged in NMR apparatus, imaging qualities such as resolution, sensitivity, linearity etc. can be read directly or measurements can be performed for this purpose.

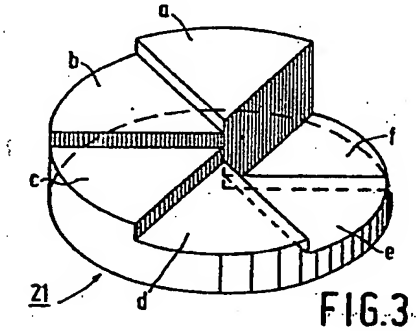

FIG.3

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Phantom for NMR apparatus.

The invention relates to a phantom for NMR imaging apparatus, comprising a plastics body which is provided with holes which are to be filled with a contrast medium for NMR measurements.

A phantom of this kind is known from a book Nuclear Magnetic Resonance imaging, edited by Partain e,o, by N.J. Sneiders et al, pages 436-445, Nr. 33, "Phantoms for NMR image analysis".

A phantom described therein is made of plexiglass and is provided with a plurality of holes of various diameters, some holes of the same diameter being arranged in a crresponding row at a uniform distance from one another which equals the diameter of the hole. The holes may be filled with water, with a suitable additive or with another so-called contrast medium such as vaseline.

A phantom of this kind is not optimally suited to the deviation of image information, notably concerning spatial resolution, direction-dependent imaging quality, linearity of the image and the like.

It is an object of the invenrion to mitigate these drawbacks; to achieve this, a phantom of the described kind in accordance with the invention is characterized in that the shape, the size and the mutual orientation of the holes exhibit a structure which is adapted to those imaging property qualities of the apparatus which are to be measured.

When such a phantom is used for measuring the imaging qualities of the apparatus, information as regards the spatial resolution, the linearity of the image, the sensitivity etc. can be obtained in a direct manner.

A preferred embodiment of the phantom comprises a cylindrical body of, for example plastics which is divided into several, for example from 6 to 12 segments, in

each of which there are provided at least a few series of holes which are situated along radial lines. The size of these holes which are preferably situated at a distance from one another which, as before, equals the transverse dimension of the hole in the line direction, differs from one segment to another. When such a phantom is used, the spatial resolution of the apparatus can be read directly from the image of the phantom. By rotating the phantom about the cylinder axis, the homogeneity of the resolution can also be checked.

A further preferred embodiment of the phantom comprises a plastics body in which there is formed a mutually orthogonal system of grooves which are to be filled with a contrast medium. Such a phantom is preferably shaped as a square cylinder and is notably suitable for the measurement of linearity in the image of the apparatus. Non-linearity in the apparatus can be caused, for example by inhomogeneities in the magnetic field. The magnitude and the direction thereof can be calculated from the image of this phantom, after which appropriate corrections can be made. A phantom also can be constructed by putting a number of tubes (for example of glass) filled with a liquid with different values for T_1 and T_2 into a vessel with a liquid adapted to the apparatus and the liquids in the tube.

A phantom which is particularly suitable for checking apparatus suitable for the simultaneous or quasi-simultaneous measurement of several slices of an object comprises, for example a number of planar spaces which is adapted to the number of slices to be simultaneously measured and which are separated by discs of plastics. The discs may then be consecutively numbered.

Some preferred embodiments in accordance with the invention will be described in detail hereinafter with reference to the drawing. Therein:

Figure 1 shows a phantom which is divided into segments and which is notably suitable for the measurement of spatial resolution,

Figure 2 shows a phantom which comprises an ortho-

gonal system of grooves which are to be filled with a contrast medium for the measurement of imaging linearity;

Figure 3 shows a phantom for sensitivity measurements, and

Figure 4 shows a phantom for multi-slice measurements.

As is shown in Figure 1, a phantom in accordance with the invention which is partocularly suitable for the measurement of spatial linearity of the image comprises a cylinder 1 which is made of plastics and which, in this case, is round; the structure of the phantom is preferably chosen so that interference with a line pattern in the display system is avoided; consequently, preferably 6 or 12 segments are chosen. The Figure shows a division into six segments A - F. In each of the segments there is provided a regular pattern of holes 3 which are arranged at least partly along straight lines. These holes may be filled with a high-contrast medium for NMR measurements, for example aqueous solutions, vaseline, etc. The holes in a first segment A are respectively arranged along the directions of the lines, for example at a distance of 6 mm from one another, the transverse dimensions of the holes, measured along the line, preferably being equal to the spacing between two successive holes. Each of the other segments is provided with holes which have the same size for that segment and also the same spacing, for example in the sequence 4, 3, 3, $1\frac{1}{2}$ and 1 mm. Also feasible is a spacing sequence which increases by a factor $\sqrt{2}$ from one segment to another. The phantom as a whole has, for example a diameter of 20 cm for head measurement apparatus and a diameter of 40 cm for body measurement apparatus, its thickness being, for example from 5 to 10 cm. In a preferred embodiment, the block is composed of exchangeable segments so that the range of spatial frequencies represented by the holes can be adapted by the exchange of one or more segments, for example, by the replacement of the 6 mm segment by, for example, a 0.6 mm segment. The supporting material of the phantom is preferably a plastics which produces an extremely small NMR

signal in comparison with the filler material in the holes, for example because of the very short relaxation times for the spin resonances therein. Some comparatively large holes 8 are preferably provided for positioning the phantom with respect to an object slice to be measured. One of these holes preferably extends from a first end face of the phantom to approximately half the axial height thereof, a second hole extending from an opposite end face again to half the axial height.

A phantom as shown in Figure 2 is particularly suitable for the measurement of spatial linearity. This phantom is also made of plastics and comprises an orthogonal system 11 of mutually perpendicular grooves 13 and 15 to be filled with a contrast medium with a pitch of, for example 20 grooves across the entire phantom for both groove systems, which phantom is for both directions 200 or 400 mm across. Using such a phantom, inhomogeneities, or in other words undesirable gradients, can be directly demonstrated in the (quasi-) steady magnetic field in the measurement space. Exact positioning of the phantom can this also be achieved. The phantom further comprises a first cover plate 17 for the first groove grid comprising, viewed in the drawing, horizontal grooves 13, a facultative intermediate plate, not shown in the drawing, the second groove grid with the grooves 15 which preferably extend transversely with respect to the grooves 13, and a second cover plate 19. The assembly formed by cover plates, grooves, grids and intermediate plates may also form one integral unit to which seals for sealing the end openings of the grooves are added. The grooves may alternatively have a different geometry, for example they may be rectangular or semicircular.

Figure 3 shows a phantom which is particularly suitable for sensitivity measurements; a body 21 is again divided into segments which differ only as regards thickness, for example 12 segments with a thickness difference for each step of approximately 8%. The Figure shows a phantom comprising 6 segments A - F, each of which is filled

with or consists of a material which produces a resonance signal which can be suitably measured. Measurements performed on such a phantom provide a direct insight into the system linearity. A particular embodiment of this phantom comprises only two segments, each of which forms a semicircle, the thickness difference being, for example approximately 1 mm. The response of the apparatus to a step function can be measured by means of this phantom.

Different properties of each of the described phantoms can also be combined in one phantom. For example, a phantom can be constructed so as to comprise a radial arrangement of, for example 12 rows of holes whose diameter decreases in the direction of the centre of the phantom, for example in the sequence 20, 12, 8, 5, 3, 2, $1\frac{1}{2}$ and 1 mm. The holes in the twelve successive radial lines have a correspondingly different depth, for example in a sequence in which the depth increases from 0.50 to 3.25 mm in steps of 0.25 mm.

A further embodiment of a combined phantom is a phantom which is suitable for measurements in apparatus for the simulatneous or at least quasi-simultaneous measurement of several slices. Such a phantom is shown in Figure 4 and comprises two cover plates 22 and 24 and en envelope 26 which is, for example, cylindrical. A housing thus formed in this case comprises 16 discs 28 of plastics which are stacked between spacers or rings 30, thus forming 16 sections 31. The second, the ninth and the fiftenth section are constructed in the same manner as the phantom described with reference to Figure 2, so that they each comprise an orthogonal system of grooves 32. Each of the discs or sections are preferably provided with a, preferably sequential, identification number, so that the orientation and position of a slice in the object can be read directly. For example, the numbers can be milled into the discs 38 so that theu can be readily recognized in an image. The discs 28 have a thickness of, for example 2 mm, each section having a thickness of, for example 8 mm. The diameter of the phantom can again be chosen so as to be, for

example 200 or 400 mm.

CLAIMS

1. A phantom for NMR imaging apparatus, comprising a plastics body which is provided with holes which are to be filled with a constrast medium for NMR measurements, characterized in that the shape, the size and the mutual orientation of the holes 3 exhibit a structure which is adapted to those imaging properties of the apparatus which are to be measured.

2. A phantom as claimed in Claim 1, characterized in that it is composed of a cylindrical block 1 which is divided into a plurality of segments A-F, and each of the segments is provided with a pattern of holes, at least one pattern sequence of holes being distributed along a straight line 7 in each of the segments, and the transverse dimension and spacing of the holes being different for each segment.

3. A phantom as claimed in Claim 1, characterized in that it comproses an orthogonal system 11 of grooves (13, 15) which are to be filled with a contrast medium.

4. A phantom as claimed in Claim 2, characterized in that the thickness of the segments varies according to an arithmetical progression.

5. A phantom as claimed in Claim 1, characterized in that it comprises two semi-circular segments with a predetermined difference in thickness.

6. A phantom as claimed in Claim 1 or 3, characterized in that it comprises a series of identified sections 31 of equal thickness.

7. A phantom as claimed in Claim 1, characterized in that it comprises holes which are situated along, for example from 6 to 18 radial lines, the transverse dimensions of said holes increasing as from the centre, the depth of the holes increasing in steps of, for example from 0.1

to 0.5 mm according to an arithmetical progression from one radial line to the next radial line.

8. A phantom as claimed in Claim 1, characterized in that it comprises tubes each filled with an adapted liquid and in a liquid filled vessel.

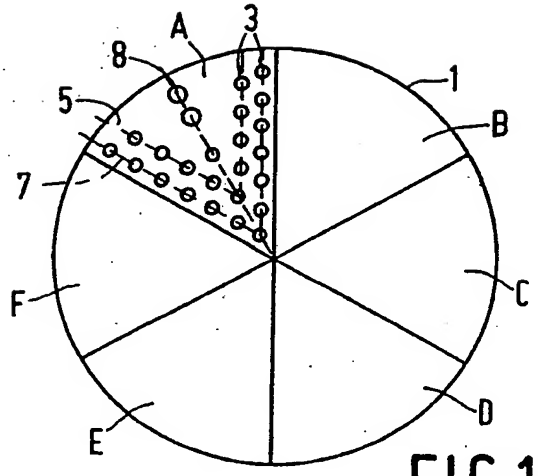

FIG.1a

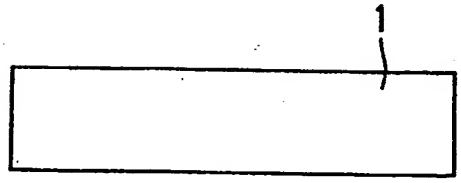

FIG.1b

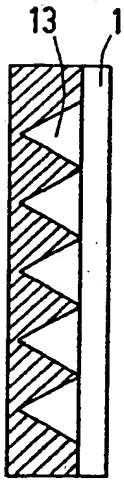

FIG.2a

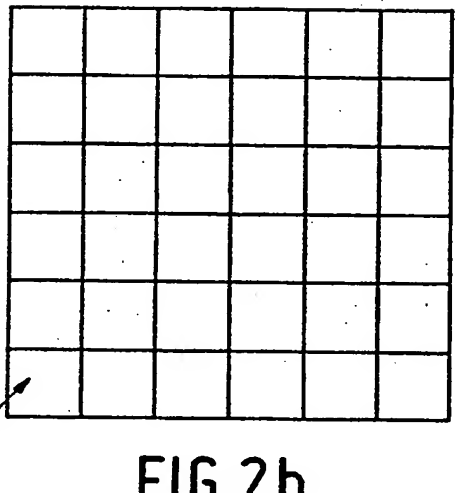

FIG.2b

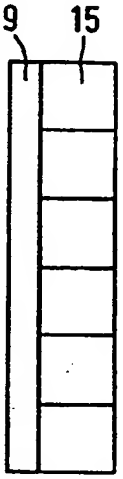

FIG.2c

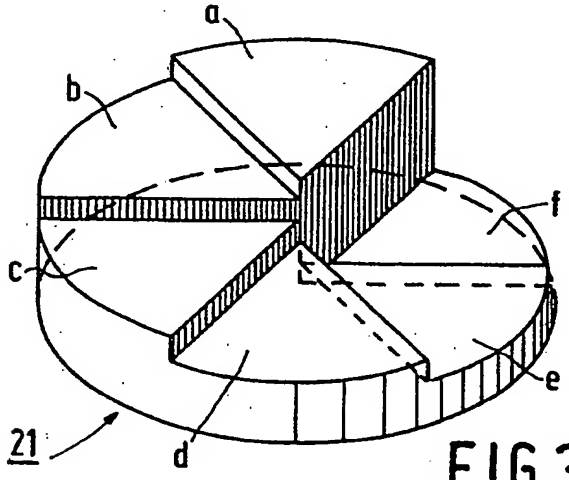

FIG.3

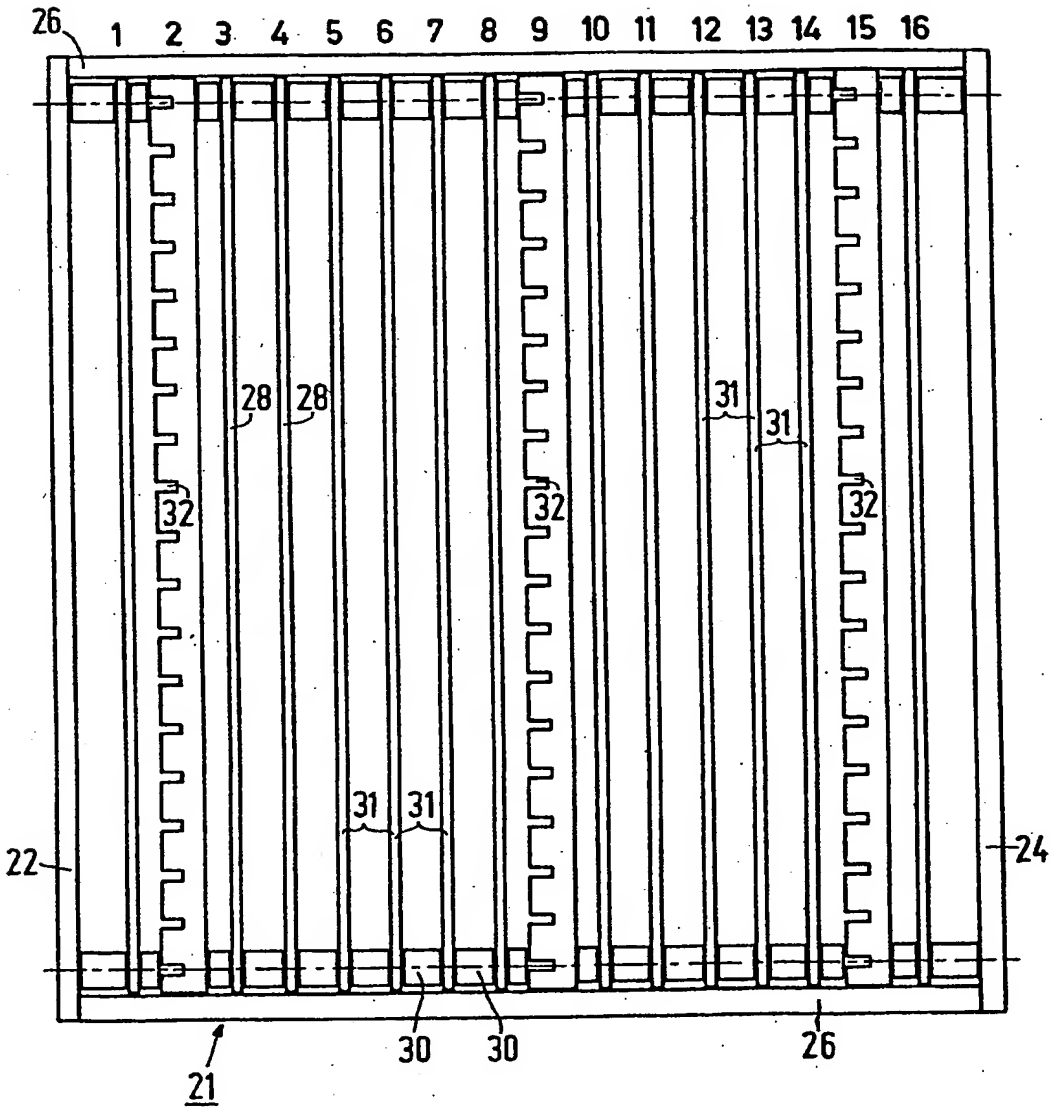
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FIG.4